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Prioritizing Candidate Decision Aids for Tactical Applications: Report of a Workshop

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This research note describes a methodology for prioritizing tactical expert systems for development. The methodology was assessed in an action officer prioritizing workshop, and the report presents lessons learned in using the methodology, recommendations for improving the methodology, and results of the prioritization. The following aids were rated as the four top candidates for expert system development: Alternate Courses of Action Analyzer, Force Movement Analyzer, Obstacle Preparation, and Fuel Consumption Rate Analyzer. Keywords:

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PRIORITIZING CANDIDATE DECISION AIDS FOR TACTICAL APPLICATIONS:
REPORT OF A WORKSHOP

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PRIORITIZING CANDIDATE DECISION AIDS FOR TACTICAL APPLICATIONS: REPORT OF A WORKSHOP

INTRODUCTION

This report describes a methodology for prioritizing candidate decision aids which can be developed using the techniques of artificial itelligence (AI). The methodology was tested in an action officer Prioritization Workshop conducted at Ft. Leavenworth in November 1986. This report details the methodology, results of the prioritization, limitations of and lessons learned from the Workshop, prioritizing issues, and general recommendations for a prioritizing methodology. → to 1473

Artificial intelligence has been identified by the Department of Defense as one of the most critical technologies to pursue for the remainder of this century (D'Ambrosio, 1985). Due to its high priority, some efficient and systematic method is needed to identify potential AI applications and projects and choose among them for funding. If the bases for development decisions are not explicitly chosen, the funding decisions will still be made, but they will be based on implicit criteria such as vendors' recommendations, political pressures, or a new technology that catches the developer's interest. Not only is it important in this time of austerity to get the most for the money spent, wasting time on projects that do not contribute to overall Army goals can put us behind in the technology race with potential adversaries. Further, more effort spent choosing between candidate aids will result in fewer abandoned developments. This report describes and assesses one such prioritizing methodology.

Artificial intelligence is a group of computer based technologies which produce results commonly thought to require human intelligence. AI is a loosely defined field and includes a number of technologies: expert systems, natural language understanding, robotics, artificial vision, sound sensing and understanding, learning, and information fusion. Because expert systems are particularly relevant to military tactical applications, this paper will be limited to expert systems. Expert systems are computer programs that are based on the knowledge that underlies human expertise. The expert has two kinds of knowledge: facts and theories found in textbooks and private knowledge gained through many years of experience. This private knowledge is not formalized but consists of rules of thumb, short cuts, and educated guesses that the expert has found to work in the past. These educated guesses, or heuristics, are especially appropriate for dealing with problem areas characterized by unreliable and incomplete data. Exact problem solving algorithms usually make certain assumptions about the reliability, completeness and the amount of error in the data they use. However, many real world problems originate in complex, changing situations with information that is uncertain and incomplete. Battlefield situations are just such problems, and expert systems hold great promise for decision making support in the uncertain, high stress, information overloaded environment of tactical battle management.

BACKGROUND

In December 1985, the Fort Leavenworth TRADOC[1] Analysis Center (TRAC, formerly CAORA) released the report "G3 Analysis" (USA CAORA, 1985), which prioritized potential tactical decision aids that would use optimization, simulation, or decision analysis techniques. AI techniques were identified as having potential for use in the development of decision aids, but the report did not evaluate the application of AI to the aids. The Combined Arms Combat Developments Activity - Command, Control, Communications and Intelligence (CACDA-C3I) Directorate requested that the Army Research Institute (ARI) Fort Leavenworth Field Unit: (1) evaluate the potential for the application of AI to the development of command and control decision aids, (2) develop a prioritizing methodology for AI based aids, (3) prioritize a set of tactical decision aids, and (4) recommend AI tools that could be used to build the aids.

The first, second, and third of these tasks were addressed in a CACDA-C3I Action Officer Prioritization Workshop, supported by ARI, in November 1986. This report documents the methodology and results of the CACDA Decision Aids Prioritization Workshop. The Workshop consisted of two phases and prioritized a subset of the aiding opportunities identified in the 1985 TRAC "G3 Analysis".

The TRAC "G3 Analysis" report analyzed G3 functions, identified 53 opportunities to aid G3 performance through the use of computer applications, and prioritized these 53 opportunities. Appendix A describes the 53 aids and Appendix B shows the results of the "G3 Analysis" report prioritizations. The first part of the Prioritization Workshop selected a subset of 23 aiding opportunities from the 53 "G3 Analysis" report aids. These 23 aids were those for which AI could be appropriately used in the design of the aid. The second part of the Prioritization Workshop was a multi-attribute analysis in which the 23 aids selected in the first part were rated on the attributes of importance and feasibility.

The remainder of this report presents the methodology, results, and lessons learned in the CACDA AI Decision Aid Prioritization Workshop, and makes recommendations for future prioritization efforts.

The fourth task, to recommend AI tools for aid development, is treated in the report, A Survey of Expert System Development Tools, (Liebhaber & Riedel, 1987). In this report, each of 93 tools is described in terms of its knowledge representation, control and inference, certainty management, hypothesis handling, and knowledge acquisition features. The cost, availability, vendor support, user interface devices and hardware and software requirements of each tool are also listed.

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[1]Training and Doctrine Command.

A forthcoming ARI report (Riedel,in preparation), which is also related to this project, will discuss prioritizing methodologies in general and make recommendations for developing an improved methodology. The report will discuss in detail criteria for choosing expert system applications, and alternative prioritization methodologies.

PROCEDURE

Purpose. The Workshop had two main purposes: (1) to identify and make a preliminary prioritization of tactical decision aids suitable for development using AI technology, and (2) to test a methodology for prioritizing AI based decision aids.

Participants. Action officers were invited from organizations currently doing tactical decision aid work. Attendees included personnel from TRAC, Command and General Staff College, Center for Army Tactics, Combined Arms Combat Developments Activity, Army Research Institute, Mitre Corporation, Army Signal Center, Army Intelligence Center, and the Soldier Support Center.

Agenda. The Workshop covered one and a half days. The first half day was used to brief the participants on background information they would need to make the prioritization judgments.

Briefings included:

1. The Army Tactical Command and Control System.

2. Introduction to Artificial Intelligence.

3. The Airland Battle Management Program and Tactical Decision Aids currently under development.

4. The Joint Army Materiel Command/TRADOC AI Working Groups.

5. The Combined Arms Center (CAC)/ARI Experimental Development Demonstration and Integration Center. (See Packard, McKeown, Falleson, Solick & Halpin, 1987, for a detailed description.)

6. The "G3 Decision Aid Analysis"

7. Prioritizing AI Tactical Decisions

After the briefings, participants then broke into two Working Groups. The first addressed the prioritization of AI tactical decision aids and the second addressed the steps in the development of AI software from idea to implementation. These meetings extended over one day. This report describes the activities of the first Working Group.

Prioritization Methodology

ARI developed a methodology to extend the procedure used in the "G3 Analysis" report. To do this it added an expert system filter prior to the multi-attribute utility analysis (MAUA) prioritization methodology used by the "G3 Analysis" report. Figure 1 shows the revised methodology. The first step is to identify a set of candidate aids. The second step is to determine

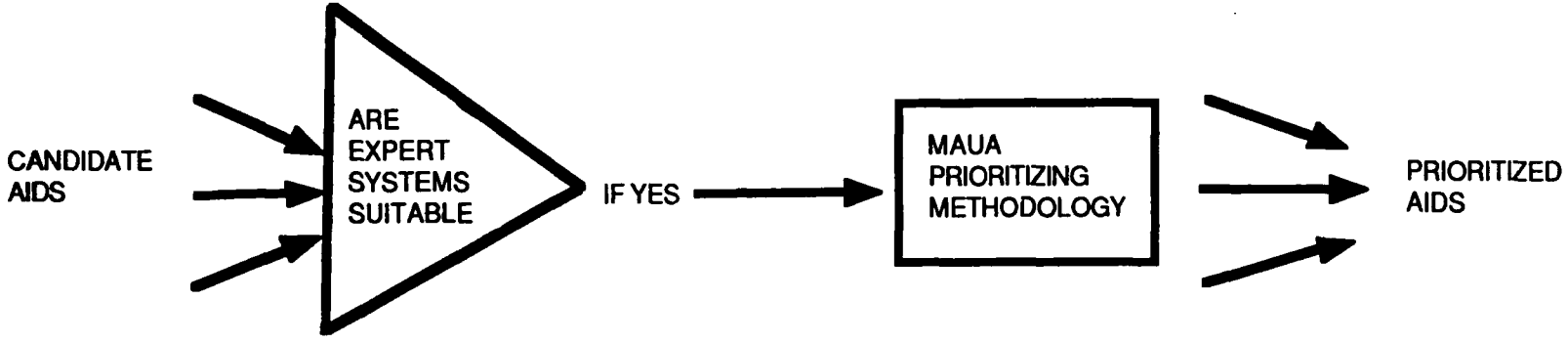

Figure 1. Prioritization methodology for AI tactical decision aids.

whether the application of expert system technology is appropriate for development of each aid. Expert systems are clearly inappropriate for some aids, and marginally appropriate for others. The third step is to apply a multi-attribute utility prioritization methodology to those aids for which AI is appropriate.

STEP 1. Identify Candidate Aids.

This is a requirements analysis, where the needs of the intended users are analyzed and aids that could meet those needs are identified. The "G3 Analysis" presents the results of a requirements analysis where 53 candidate aids were identified. The Workshop bypassed Step 1 and used the 53 aids identified in the "G3 Analysis" as input to Step 2.

STEP 2: Determine the Appropriateness of Expert System Technology for Each Aid.

Not all the problem areas that could benefit from automated systems are appropriate areas for the application of expert systems. A review of the literature in expert systems was conducted to derive criteria to use in selecting applications for expert systems. From this review the following emerged as necessary characteristics of the problem area and experts in that area:

- o Experts exist in the problem area.
- o Experts agree on the correct solution and how to proceed.
- o Experts can describe their procedures.
- o Other aiding methods would not be satisfactory.

Three Army officers, two lieutenant colonels and one major who were familiar with G3 tactical decisions and ES technology, were asked to evaluate each of the 53 candidate aids on the above criteria.

Twenty-two of the original 53 aids met all the criteria and were passed on to the next step. The raters also added one aid, Situation Assessment, to the list of potential AI aids. Table 1 lists the 23 aids that were identified in this step.

STEP 3: Compare Candidate Aids.

Multi-attribute Utility Analysis (MAUA) was used to compare the aids with each other. MAUA is a technique for aiding decision problems that are characterized by multiple objectives. It is based on the principle of decomposition. The objectives in choosing an aid for development are broken into component parts, analyzed, and then combined to yield composite judgments for each aid which can then be used to rank order the aids. There are a number of versions of MAUA (cf. Edwards, 1977; Keeney & Raiffa, 1976; Pitz & McKillip, 1984). This version is similar to that of Edwards (1977).

Table 1

Tactical Decision Aiding Opportunities Suitable for
Expert System Development

Forecast Tube Replacement
Controlled Supply Rate (CSR)
Prescribed Chemical Load (PCL)
Force Movement Analyzer
Fuel Consumption Rates
Air Movement Planner
Denial Preparation
Compare Alternative Courses of Action
Obstacle Preparation
Chemical Effects Preparation
Expenditure Rates (Fire Support Annex)
Basic Load Allocations
Nuclear Effects Prediction
Aircraft Asset Analyzer
Priorities/Allocation (Air Defense Annex)
Rear Area Protection Capabilities
Fallout Prediction (Nuclear)
NBC Effects Evaluation
Assign Psychological Operations Assets
Air Movement Analyzer
Situation Assessment
Optimal Atomic Demolition Munitions Employment
Nuclear Effects Prediction

MAUA is especially appropriate for competing objectives. For example, one objective in choosing an aid for development may be to develop an aid for an important problem, that is, where there will be a great increase in the effectiveness of the decision when using the aid. One may also wish to maximize the probability of successfully developing the aid. If there is a lot of room for improvement using the aid this means the problem is probably complex and difficult. This also means that well established procedures for solving the problem have not been developed, and it is likely that the AI technology for developing the aid may still be rudimentary. The person prioritizing the aids must decide how much importance he is willing to trade off for a decreased risk in implementing the aid. MAUA provides procedures for making such tradeoffs.

MAUA Prioritization Steps

1. Identify the criteria for ranking the aids. These are the aspects of the aids the decision maker wants to maximize with his/her rankings. In this case, criteria were taken from "G3 Analysis", which specified importance of the aid and feasibility of implementation as aspects of the aids that would determine their rankings.

2. Identify the subcriteria and how they are to be measured. Subcriteria are component parts of each criteria. The "G3 Analysis" report defined importance as being composed of: (a) time and quality savings in using the aid, (b) frequency with which the aid will be used, and (c) number of Commander's Critical Information Requirements (CCIR) the aid incorporates. Feasibility was broken down into: (a) economical - estimated cost of developing and implementing the aid, (b) technical - probability that the needed technology exists to develop the aid within the next five years, and (c) operational - probability that the aid will be successfully fielded.

3. Weight the criteria and subcriteria. The weight reflects how much each criteria and subcriteria contributes to the overall desirability of the aid. The weights used in the Workshop were taken from the "G3 Analysis", which used the Saaty method of weighting (Saaty, 1980). In this method raters are asked to make comparisons of relative importance between pairs of criteria and similarly between pairs of subcriteria. The weights selected are shown in Figure 2.

4. Obtain a value for each candidate aid on each subcriteria. This step was the primary activity of the Workshop. Twelve raters participated in the Prioritization Workshop. Raters were given a rating sheet for each of the 23 candidate aids and asked to rate each aid on a scale of one to ten on each subcriterion. Appendix C shows a sample rating sheet. Average rating across participants were obtained for each aid on each attribute. A measure of rater agreement, Chronbach's alpha (SPSSX Users' Manual, 1983), was calculated for each aid. Appendix D shows the interrater correlations. Examination of this table shows that for many of the aids there was little or no agreement among the raters on the ratings that were assigned to the subcriteria. In cases where there was a wide variation between raters' scores, raters discussed the reasons for their ratings and arrived at a consensus. For those ratings that were discussed, the consensus score was used in Step 5 for X(ij) rather than an averaged rating.

5. Aggregate the weighted scores for each option. A total score, for each candidate aid was calculated using the following formula:

$$T(_i) = \Sigma w(j)\ x(ij)$$

Where T(i) is the total score for candidate aid i, w(j) is the weight of subcriterion j, x(ij) is the averaged rating of aid i on subcriterion j.

The average rating of each aid on each attribute was weighted and summed to yield a total score for each aid.

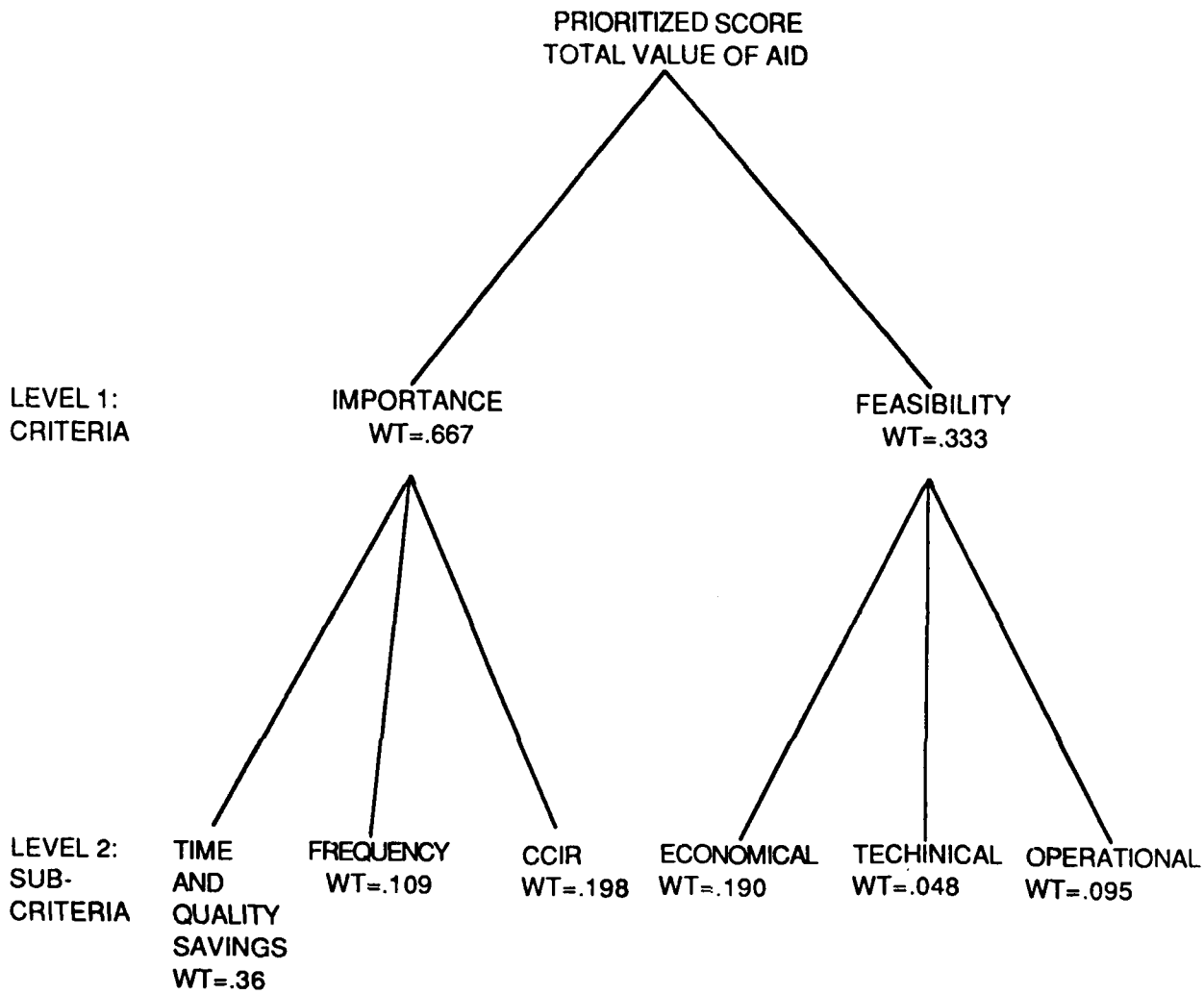

Figure 2. Hierarchy of aid criteria.

6. Conduct a sensitivity analysis. A sensitivity analysis makes changes in the weights and possibly criteria and subcriteria to see how these changes affect the rankings. This analysis enables an evaluation of the robustness of the rankings and an examination of which variables are critical in producing the rankings which were obtained. In the Workshop, the sensitivity analysis was done by changing the weights of the criteria and subcriteria. Weighted and unweighted total scores were calculated, and the results were presented to the participants. Where there were large discrepancies between the weighted and unweighted scores for an aid, possible reasons for the discrepancies were discussed.

7. Rank the aids. Candidate aids are ranked based on their aggregated weighted scores T(i).

RESULTS

Table 2 shows the twelve top ranking aids and their ranks. The top four aids are Alternative Courses of Action Analyzer, Force Movement Analyzer, Obstacle Preparation, and Fuel Consumption Rate Analyzer. Descriptions of these aids can be found in Appendix A.

Table 2

Prioritization Rank of Top Twelve Candidate Aids

Aid Descriptors	Rank	
	Absolute	Weighted
Compare Alternative Courses of Action (COA)	1	1
Force Movement Analyzer	2	2
Obstacle Preparation	3	4
Fuel Consumption Rates	4	3
Denial Preparation	5	5
Basic Load	6	12
Priorities Allocation	7	6
Chemical Effects Prediction	8	10
Optimal Atomic Demolition Munitions Employment	9	9
Rear Area Protection Capabilities	10	7
Situation Assessment	11	11
Air Movement Analyzer	12	8

A sensitivity analysis, comparing weighted and unweighted rankings, shows that the set of the twelve highest ranking aids is the same for both the weighted and unweighted rankings. Similarly, the sets of five highest ranking aids is the same. This suggests that these sets of the top five and the top twelve aids are relatively robust.

There are, however, several cases with large discrepancies between the weighted and unweighted ranks of an aid. Aids with large discrepancies are Air Movement Analyzer, Basic Load, and Rear Area Protection Capabilities. The reason for these discrepancies is apparent when the raw data are examined. The CCIR subcriterion has a relatively high weight; it accounts for over a third of the total weight. Both Air Movement Analyzer and Rear Area Protection Capabilities have high ratings on CCIR and low ratings on the other attributes. The high CCIR score, with its high weighting, raises the ranking of these aids compared to the unweighted ranking. Basic Load on the other hand has a very low CCIR score and high scores on the other variables. Weighting the CCIR score makes its low value have more of an effect and drags down the relative total score of the Basic Load aid. These discrepancies suggest that both the use and weight of the subcriterion "CCIR" should be re-examined.

The interrater reliability of the Workshop participants' ratings vary from .875 to 0. See Appendix D. However, the four top rated aids all had reliabilities over .62, an acceptable reliability for ratings of this type. Further, the top rated aid, Compare Alternate Courses of Action, had an interrater reliability of .875. This means that Workshop participants tended to agree on the top four aids, and to highly agree that the top aid should be Compare Alternate Courses of Action.

PROBLEMS/LIMITATIONS OF THE WORKSHOP

Raters. It is very important to use raters with expertise in the areas being judged. In the Workshop, raters with little background in AI were asked to make technical feasibility and cost ratings. Similarly, personnel with little experience in G3 operations were asked to rate the aids on importance. In the Workshop, raters were asked to omit the ratings on a particular dimension if they didn't feel qualified to do the ratings. However, as the many zero interrater correlations in Appendix D indicate, many raters did not have the required expertise with which to make the ratings. There is no reason why different raters could not provide data for the different ratings that are required.

In this prioritization methodology, four types of ratings are required: (1) ratings of the appropriateness of ES technology for the candidate aids' development in Step 2; (2) the assignment of weights to the criteria and subcriteria in Step 5 of the MAUA prioritization; (3) ratings of the potential contribution of the aid to improvement in battlefield outcome; and (4) ratings of the feasibility of developing and implementing the aid. Each of these types of ratings requires a different area of expertise. The first type requires expertise in both AI technology and military tactical operations. The rater should be knowledgeable about tactical operations so that he understands what functions the aid would perform. He should have a background in AI so that he can judge whether AI technologies can best support those functions. The three officers rating the appropriateness of ES technology had both of these types of expertise. The second type of rating, criterion and subcriterion weights, is best made by those who will make the decision of which aids to develop and implement. These are not judgements of fact or information but judgements of value and preference. That is, the rater must decide what he wants to accomplish with his choice of aids to develop. The third type of rating, rating of the importance of the candidate aid, requires expertise in tactical operations and the fourth type, ratings of feasibility requires expertise in AI. If the same raters do not have the expertise, and in the case of the weighting judgements, the role to make all of these ratings, then different raters should be used to make the different judgements required by the methodology.

In the Workshop, different raters made the ratings of ES appropriateness and the feasibility and importance criteria ratings. As the low interrater agreement correlations indicate, all the raters did not have the needed expertise to do the subcriteria ratings. However, discussing the ratings for which there was a large amount of disagreement helped mitigate the effects of using the wrong raters.

Rating Anchors. The rating scales need anchors. For example, the meaning of cost is unclear. What is high to one person may be intermediate to another. If high cost means $500,000 to one person and 3 million to another, an aid estimated to cost $500,000 might be rated as a 10 by the first and a one by the other.

CCIR. This subcriterion measures the number of major subcategories of CCIR which the aid supports. It was included in the TRAC "G3 Analysis" because the authors felt that aid utility increases with increasing production/support of CCIR. Workshop participants thought that some CCIR may be more critical than

others and contribute more to the total score. There should not be, therefore, a direct relationship between number of CCIR and the aid's prioritization score. Participants thought the method of calculating this CCIR score should be re-examined. Further, many participants thought the large weight of this subcriterion was inappropriate.

Aggregation Formula. Workshop participants questioned the additive aggregation formula that was used. However, no alternative was suggested. Under the formula used, weighted scores are simply added up for each aid. This means that if an aid had no feasibility at all, i.e., could not be developed, it could still get a high ranking if it were rated very important. One participant suggested that multiplying the importance score by the feasibility score would give a ranking closer to an intuitively correct ranking.

Overall Methodology. The "best" methodology will depend on the developer's objectives and the relationship between them. MAUA and the Saaty methodology are "trade off" methods. That is, the developer is willing to accept a bad rating on one variable in order to get a very good rating on another variable. For example, in order to get an aid with a great potential for time savings, the developer may be willing to accept a high risk of development. He will accept a high risk in order to get a higher payoff. This "trade off" model is not appropriate for some sets of funding objectives. For example, a funding objective may be to allocate a certain amount of money to fund projects in each of the high, medium, and low risk categories. In this case, including "risk" as a MAUA variable would not correctly model the developer's funding objectives. In this case, a portfolio model (Sowder & Mandakovic, 1986) used in combination with a MAUA model would be appropriate. The point to be made is that a MAUA or Saaty prioritizing methodology is not apriori the best methodology. However, for this Workshop MAUA appears appropriate.

Criteria. The criteria should be determined by the objectives of those who will fund the aids' development. Therefore, subsequent prioritization efforts will not necessarily use the same criteria as those used in this Workshop. For example, if an objective of the developers is to fund aids which would contribute to the development of ES technology, then this would be an additional criterion.

CONCLUSIONS AND RECOMMENDATIONS

As stated previously, the Workshop had two purposes: (1) to develop and prioritize a list of tactical decision aids suitable for development using AI technology, and (2) to test a methodology suitable for prioritizing AI based aids. The following conclusions and recommendations address these purposes.

Prioritized Aids. The four top ranked aids were Alternate COA Analyzer, Force Movement Analyzer, Obstacle Preparation and Fuel Consumption Rates Analyzer. All four had high interrater agreement and ranked the same using both weighted and unweighted scores. These results contribute credibility to the rankings of the four top rated aids. The four aids are also found among the top rated aids of other priorization efforts, which used different criteria and different candidate lists (e.g., Archer, Carter,& Murray, in preparation; USA CAORA, 1985; Coleman & Miller, in preparation). Although this priorization Workshop was a preliminary effort, the results suggest that the four top rated aids should be considered as candidates for AI based development.

Prioritization Methodology. The following general recommendations are made for a prioritization methodology. These recommendations will be elaborated in a subsequent report (Riedel, in preparation).

1. Prioritization should be viewed within the context of the larger aid development process. The major components are: (1) requirements analysis to identify candidate aids, (2) identification of prioritization criteria, (3) identification of prioritization model, (4) data collection including a feasibility assessment, (5) application of prioritization model, (6) selection of set of aids for development.

2. In collecting the data, the right data sources need to be identified. The same raters need not supply all the data. Results will be no better than the relevance and accuracy of the data going into the prioritization formula.

3. The key to successful prioritization is in defining the appropriate objectives, the relationship between them, and identifying criteria to measure whether the objectives are fulfilled. The choice of the prioritization variables, formula, variable weights and overall methodology should be made by those who will make the decisions about which aids to fund. These elements are determined by the developer's objectives in choosing aids, and it is through these elements that aid selection is related to overall management goals.

4. There are a variety of prioritization models available, and the best model depends on the developer's objectives and how these objectives are related to one another.

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APPENDIX A

List of G3 Main Analytic Aiding Opportunities

Following is a list of 53 G3 Main analytic aiding opportunities identified in the "G3 Analysis" report (CAORA, 1985). The list shows the aid names, the analytic technique(s) to be employed.

Air Movement Analyzer

a. Product supported: Movement Order
b. Description: This aid is designed to analyze whether there are sufficient time and assets to accomplish the stated mission.
c. Analytic techniques: math model (MM), simulation (SIM), artificial intelligence (AI)

Air Movement Planner

a. Product supported: Movement Order
b. Description: This aid is designed to automate the "stubby pencil" calculations of an air movement table.
c. Analytic techniques: MM, optimization technique (OT)

Aircraft Asset Analyzer

a. Product supported: Aircraft Mission Request (Army Aviation)
b. Description: This aid is designed to analyze whether sufficient aviation assets exist on mission, time frame, and priority.
c. Analytic techniques: MM, SIM

Aircraft Requirements

a. Product supported: Army Aviation Annex
b. Description: This aid is designed to determine number of aircraft required to support the mission.
c. Analytic techniques: MM, AI, SIM

Allocate Combat Air Support (CAS) and Reconnaissance (RECCE) Aircraft

a. Product supported: Air Request/Task Message
b. Description: This aid is designed to determine best utilization of CAS and RECCE aircraft.
c. Analytic techniques: DA, SIM, AI

Allocate Critical Assets (ECM)

a. Product supported: ECM Mission Request
b. Description: This aid is designed to determine the optimal way to allocate limited ECM assets.
c. Analytic techniques: SIM, MM, AI

Allocate Replacement Equipment, Supplies, and Troops

a. Product supported: Service Support Annex
b. Description: This aid is designed to determine the best use of replacement equipment, supplies, and troops.
c. Analytic Techniques: Decision analysis (DA), MM, SIM, OT, AI

Allocate Resources

a. Product supported: Engineer Mission Coordination Sheet

b. Description: This aid is designed to allocate critical resources within the Engineer functional area.
c. Analytic techniques: MM, SIM, DA, AI

Assign Critical Replacement Units, Personnel, and Materiel

a. Product supported: Allocate/Prioritize Replacement Personnel, Meteriel, and Units
b. Description: This aid is designed to make allocations based on need and is similar to aid 3-6, above.
c. Analytic techniques: DA, MM, SIM, OT, AI

Assign PSYOP Assets

a. Product supported: Psychological Operations Annex
b. Description: This aid is designed to optimally assign psychological elements and equipment.
c. Analytic techniques: DA, AI, MM, OT, SIM

Basic Load Allocations

a. Product supported: OPORD (Service Support)
b. Description: This aid is designed to determine basic load based on ammunition availability, intensity of conflict, and resupply.
c. Analytic techniques: MM, AI, SIM

Chemical Effects Prediction

a. Product supported: Chemical Strike Warning
b. Description: This aid is designed to determine potential effects and recommended actions to minimize those effects.
c. Analytic techniques: MM

Combat Effectiveness (Obstacles)

a. Product supported: Engineer Spot Report
b. Description: This aid is designed to evaluate the effectiveness of barriers and obstacles.
c. Analytic techniques: MM, OT

Compare Alternative Courses of Action

a. Product supported: Operations Estimate
b. Description: This aid is designed to analyze alternatives.
c. Analytic Techniques: DA, AI, MM, OT, SIM

Control Procedures/Status

a. Product supported: Airspace Management Annex
b. Description: This aid is designed to analyze various control methods.
c. Analytic techniques: DA, SIM, AI

Controlled Supply Rate (CSR)

a. Product supported: OPORD (Service Support)
b. Description: This aid is designed to analyze ammunition expenditure rates, and where required, recommend control rate restrictions.
c. Analytic techniques: MM

Damage Analysis (Effects on Enemy)

a. Product supported: Post-Strike Analysis (Nuclear)
b. Description: This aid is designed to evaluate the impact of the damage and the various options of repair.
c. Analytic techniques: DA, SIM

Denial Preparation

a. Product supported: Engineer Annex-Denial Appendix
b. Description: This aid is designed to prioritize the placement of appropriate obstacles.
c. Analytic techniques: OT, MM, SIM, AI, DA

Determine Replacement Priorities

a. Product supported: OPORD (Service Support)
b. Description: This aid is designed to assign replacement priorities based on mission, strength, and location.
c. Analytic techniques: DA, SIM, AI

Evaluate Damage Repair Alternatives

a. Product supported: Engineer Report (Damage)
b. Description: This aid is designed to evaluate the impact of the damage and the various options of repair.
c. Analytic techniques: DA, SIM

Expenditure Rates

a. Product supported: Fire Support Annex
b. Description: This aid is designed to determine expenditure rates and, when necessary, CSR based on mission and unit.
c. Analytic techniques: MM, OT, DA, SIM

Fallout Prediction

a. Product supported: Post-Strike Analysis (Nuclear)
b. Description: This aid is designed to predict fallout as a result of a nuclear strike.
c. Analytic techniques: MM

Force Movement Analyzer

a. Product supported: OPORD (Execution)
b. Description: This aid is designed to investigate force movement alternatives and time required for force movement.
c. Analytic techniques: MM, SIM

Forecast Tube Replacement

a. Product supported: Artillery Situation Report
b. Description: This aid is designed to forecast artillery tube replacement requirements based on current status and future mission.
c. Analytic techniques: MM

Forecast Unit Status

a. Product supported: Project Unit Status
b. Description: This aid is designed to project unit status based on mission, current status, and environment factors; when necessary, it would activate a critical situation alert.
c. Analytic technique: MM

Forecast Usage Rates

a. Product supported: Required Ammunition Supply Rate Report
b. Description: This aid is designed to forecast ammunition usage based on mission and unit status.
c. Analytic techniques: MM, SIM

Fuel Consumption Rates

a. Product supported: OPORD (Service Support)
b. Description: This aid is designed to determine fuel requirements based on type vehicles, mission, terrain, weather, etc.
c. Analytic techniques: MM

Hazard Areas

a. Product supported: NBC 5 (Report of Areas of Actual Contamination)
b. Description: This aid is designed to determine actual contamination areas.
c. Analytic techniques: MM, AI

Integrated CAS with Fire Support Plan

a. Product supported: Air Request/Task Message (Pre-planned)
b. Description: This aid is designed to integrate close air support with overall fire support plan.
c. Analytic techniques: DA, AI, SIM

NBC Effects Evaluation

a. Product supported: NBC 2 (Evaluated Data Report)
b. Description: This aid is designed to evaluate NBC strike data.
c. Analytic techniques: MM, SIM

Nuclear Effects Preparation

a. Product supported: Nuclear Strike Warning
b. Description; This aid is designed to determine potential effects and recommended action to minimize those effects.
c. Analytic techniques: MM

Obstacle Emplacement Plan

a. Product supported: Engineer Barrier Report
b. Description: This aid is designed to optimally select types and locations of obstacles.
c. Analytic techniques: OT, MM, SIM, DA, AI

Obstacle Preparation

a. Product supported: Engineer Annex - Obstacle Appendix
b. Description: This aid is designed to prioritize work based on critical resources.
c. Analytic techniques: OT, MM, SIM, DA, AI

Operational Effectiveness

a. Product supported: Psychological Operations Annex
b. Description: This aid is designed to estimate the operational effectiveness of a given PSYOP course of action.
c. Analytic techniques: DA, MM

Optimal Atomic Demolition Munitions (ADM) Employment

a. Product supported: Engineer Annex - ADM Appendix
b. Description: This aid is designed to optimally select and emplace ADM.
c. Analytic techniques: OT, MM, SIM, DA, AI

Optimal Friendly Employment (EW)

a. Product supported: Electronic Warfare Annex
b. Description: This aid is designed to optimally employ electronic warfare assets.
c. Analytic techniques: SIM, AI, OT, DA

Organize for Combat (FS)

a. Product supported: Fire Support Annex
b. Description: This aid is designed to effectively organize for combat.
c. Analytic techniques: DA, AI, MM

Predict Contamination (ID Affected Units)

a. Product supported: NBC 3 (Immediate Warning of Expected Contamination)
b. Description: This aid is designed to calculate expected hazard area and determine affected units.
c. Analytic techniques: MM, SIM

Pre-position Decon Supplies

a. Product supported: NBC Defense Annex
b. Description: This aid is designed to ascertain the best location and quantities for pre-positioning.
c. Analytic techniques: DA, SIM, AI

Prescribed Chemical Load (PCL)

a. Product supported: Fire Support Annex
b. Description: This aid is designed to allocate chemical munitions based on availability, mission, and release policy.
c. Analytic techniques: MM, DA, AI

Prescribed Nuclear Load (PNL)

a. Product supported: Fire Support Annex
b. Description: This aid is designed to allocate nuclear munitions based on availability, mission, and release policy.
c. Analytic techniques: MM, DA, AI

Priorities of Fire

a. Product supported: Fire Support Annex
b. Description: This aid is designed to assign priorities of fire to field artillery units.
c. Analytic techniques: DA, SIM, OT, AI

Priorities/Allocation (ADA)

a. Product supported: Air Defense Annex
b. Description: This aid is designed to establish weapon control procedures and allocate weapon systems.
c. Analytic techniques: DA, MM, SIM, DA, AI

Rear Area Protection Capabilities

a. Product supported: Rear Area Protection Annex
b. Description: This aid is designed to evaluate rear area protection plans and identify assets for the rear battle.
c. Analytic techniques: SIM, MM, DA

Relative Combat Power

a. Product supported: Operations Estimate
b. Description: This aid is designed to estimate friendly and relative combat power.
c. Analytic techniques: MM

Route Evaluation (AVN)

a. Product supported: Aircraft Mission Request (Army Aviation)
b. Description: This aid is designed to evaluate a selected flight route in terms of risk and protection.
c. Analytic techniques: DA, AI, MM

Target Allocation

a. Product supported: Chemical Support Annex
b. Description: This aid is designed to select chemical targets based on priority and chemical munitions availability.
c. Analytic techniques: SIM, AI, OT, DA

Target Susceptibility

a. Product supported: NBC Defense Annex
b. Description: This aid is designed to evaluate friendly units' susceptibility to an enemy NBC strike.
c. Analytic techniques: DA, SIM, AI

Task Organization

a. Product supported: OPORD (Task Organization)
b. Description: This aid is designed to organize combat and combat support units for combat based on mission, terrain, unit status, etc.
c. Analytic techniques: DA, AI, MM

Terrain Management

a. Product supported: OPORD (Execution)
b. Description: This aid is designed to assign units to terrain.
c. Analytic techniques: MM, OT, SIM

Time Analyzer

a. Product supported: Warning ORder
b. Description: This aid is designed to time-sequence critical actions to ensure subordinate units have time to execute.
c. Analytic techniques: MM, DA

Troop Exposure

a. Product supported: NBC Defense Annex
b. Description: This aid is designed to evaluate and monitor NBC status of units.
c. Analytic techniques: MM

Unit Movement Planner

a. Product supported: Movement Order
b. Description: This aid is designed to plan and publish movement orders for units, brigade, and below.
c. Analytic techniques: MM, SIM, AI, OT

Appendix B

Analytic Aiding Opportunities (adjusted rank order)1

AID DESCRIPTOR	Aid ID#	Adjusted Rank	Raw Rank	Absolute Rank Diff	Adjusted Importance Rank	Adjusted Feasibility Rank
Unit Movement Planner	3-51	1	1	0	1	12
Force Movement Analyzer	3-24	2	3	1	2	11
Air Movement Analyzer	3-04	3	4	1	4	19
Fuel Consumption Rates	3-26	4	5	1	7	10
Air Movement Planner	3-05	5	2	3	13	3
Assign Critical Replacement Units, Personnel, and Materiel	3-08	6	6	0	11	13
Terrain Management	3-46	7	12	5	10	29
Denial Preparation	3-19	8	22	14	12	30
Time Analyzer	3-47	9	7	2	28	4
Pre-Position Decontamination of Supplies	3-18	10	17	7	15	27
Compare Alternate Courses of action	3-13	11	42	31	3	49
Obstacle Preparation	3-31	12	14	2	17	28
Predict Contamination (ID Affected Units)	3-39	13	9	4	36	2
Forecast Unit Status	3-52	14	30	16	6	40
Chemical Effects Prediction	3-30	15	18	3	23	18
Expenditure Rates (FS)	3-22	16	11	5	33	6
Basic Load Allocations	3-10	17	8	9	42	1
Nuclear Effects Prediction	3-21	18	16	2	30	15
Aircraft Asset Analyzer	3-02	19	10	9	26	21
Priorities of Fire (FS)	3-40	20	24	4	18	32
Priorities/Allocation (ADA)	3-38	21	33	12	9	43
Rear Area Protection Capabilities	3-41	22	39	17	8	45

1 "G3 Analysis" Report

Analytic Aiding Opportunities (adjusted rank order)
(CONTINUED

AID DESCRIPTOR	Aid ID#	Adjusted Rank	Raw Rank	Absolute Rank Diff	Adjusted Importance Rank	Adjusted Feasi-bility Rank
Troop Exposure (NBC)	3-50	23	19	4	35	17
Evaluate Damage Repair Alternatives	3-17	24	27	3	21	31
Forecast Tube Replacement (FS)	3-25	25	13	12	39	9
Forecast Usage Rates (RSR)	3-53	26	23	3	32	23
Allocate CAS and RECCE	3-11	27	28	1	31	25
Controlled Supply Rate (CSR)	3-15	28	13	15	43	7
Route Evaluation (AVN)	3-44	29	35	6	5	52
ADM Employment	3-33	30	29	1	38	20
Task Organization	3-45	31	31	0	22	34
Target Allocation (Chemical)	3-48	32	25	7	40	16
Aircraft Requirements	3-03	33	32	1	25	35
Prescribed Nuclear Load (RNL)	3-37	34*	26	8	37	22
Prescribed Chemical Load (PCL)	3-36	34*	26	8	37	22
Optimal Friendly Employment (EW)	3-34	35	36	1	14	44
Organize for Combat (FS)	3-35	36	37	1	24	36
Allocate Engineer Resources	3-07	37	15	22	41	26

*Ties were allowed for ranks. PCL and PNL had a tie for all scoring schemes. Therefore, the adjusted ranks ranged from 1-52 for a total of 53 aiding opportunities.

Analytic Aiding Opportunities (adjusted rank order)
(CONTINUED)

AID DESCRIPTOR	Aid ID#	Adjusted Rank	Raw Rank	Absolute Rank Diff	Adjusted Importance Rank	Adjusted Feasi-bility Rank
Target Susceptibility (NBC)	3-49	38	34	4	27	37
Fallout Prediction (Nuclear)	3-23	39	21	18	48	8
Hazard Areas (NBC)	3-27	40	20	20	45	14
Allocate Replacements	3-06	41	43	2	16	48
Obstacle Emplacement Plan	3-30	42	41	1	29	39
Integrate CAS (FS)	3-28	43	44	1	20	42
Relative Combat Power	3-42	44	45	1	34	38
Control Procedure (A2C2)	3-14	45	46	1	19	51
NBC Effects Evaluation	3-29	46	38	8	47	24
Post-Strike Analysis (Nuclear)	3-16	47	31	16	50	5
Determined Replacement Priorities	3-43	48	47	1	44	41
Allocate Critical Assets (ECM)	3-01	49	40	9	51	33
Assign PSYOP Assets	3-09	50	49	1	46	47
Obstacle Effectiveness	3-12	51	48	3	49	46
PSYOP Effectiveness	3-32	52*	50	2	52	50

* Ties were allowed for ranks. PCL and PNL had a tie for all scoring schemes. Therefore, the adjusted ranks ranged from 1-52 for a total of 53 aiding opportunities.

APPENDIX C

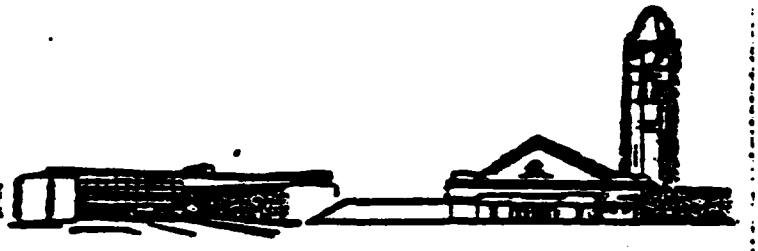
SAMPLE AID PRIORITIZATION WORKSHEET

1. AID DESCRIPTOR: Task Organization
2. AID NUMBER: 3-45
3. PRODUCT SUPPORTED: OPORD (Task Organization)
4. PRIMARY ANALYTIC TECHNIQUE: Decision Analysis
5. SUPPORTING ANALYTIC TECHNIQUE(S): Artificial Intelligence, Math Model
6. TASK(S) SUPPORTED (BY NUMBER): 1a, 1b, 3a
7. CCIR SUPPORTED (TOTAL NUMBER): 11
8. BRIEF AID DESCRIPTION: This aid is designed to organize combat and combat support units for combat based on mission, terrain, unit status, etc.
9. RANKING BY SCALES (IMPORTANCE):

	RAW SCORE	VT	ADJ SCORE
a. Frequency (Low, High)	4.3	.109	.469
b. Time and Quality Savings (Small, Large)	6.1	.198	1.208
c. CCIR (Few, Many)	3.3	.360	1.188

10. RANKING BY SCALES (FEASIBILITY):

a. Operational (Low, High)	5.6	.190	1.064
b. Economical (High Cost, Low Cost)	4.7	.048	.226
c. Technical (High Risk, Low Risk)	6.5	.095	.617
TOTAL SCORES:	30.5	1.000	4.772



COMBINED ARMS CENTER

APPENDIX D

INTERRATER AGREEMENT ON RATINGS OF AID IMPORTANCE AND FEASIBILITY

Aid	Chronbach's alpha	Number of Raters
1. Prescribed Nuclear Load	0	7
2. Rear Area Protection Capabilities	.724	9
3. Situation Assessment	.791	9
4. NBC Effects Evaluation	.449	9
5. Air Movement Planner	0	6
6. Prescribed Chemical Load (PCL)	0	7
7. Air Movement Analyzer	0	7
8. Nuclear Effects Prediction	.3191	9
9 Priorities/Allocation (ADA)	.374	7
10. Compare Alternative Courses of Action	.875	10
11. Force Movement Analyzer	.617	7
12. Expenditure Rates (FS)	0	9
13. Assign PSYOP Assets	0	7
14. Obstacle Preparation	.610	9
15. Chemical Effects Prediction	.096	9
16. Fuel Consumption Rates	.725	8
17. Basic Load Allocations	0	8
18. Optimal Atomic Demolition Munitions Employment	.230	9
19. Aircraft Asset Analyzer	0	9
20. Controlled Supply Rate (CSR)	.080	8
21. Fallout Prediction (Nuclear)	0	8
22. Forecast Tube Replacement	.706	7
23. Denial Preparation	.041	10